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Morphology of the plasmaspheric plasma boundary as observed with POLAR HYDRA and PWI, and LANL MPA

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A. Abstract

One of the interesting features observed at the plasmasphere/plasmasheet boundary is a heating of the cold plasmaspheric ions from the normal < 10 eV energies to energies up to tens of eV. It is this extension to higher energies in the cold ion distribution that is observable by HYDRA, and which delineates the outer boundary of the plasmasphere. The cold ion population proper is below the energy threshold for HYDRA ions. POLAR PWI can be used to detect the cold plasmaspheric ion population which dominates the ion density in this region with densities of up to 100 cm^{-3}. During each pass through the inner magnetosphere POLAR samples down to $L = 3.5$ at two different MLTs, thereby providing a two-point fix on the location of the plasmapause. In this study we will attempt to establish the three-dimensional morphology of the outer edge of the plasmasphere using POLAR measurements for radial coverage and LANL-MPA measurements on several geosynchronous satellites for local time coverage. We will further try to establish the geomagnetic conditions which lead to the observed heated tail of the cold ion distribution at the outer edge of the plasmasphere.

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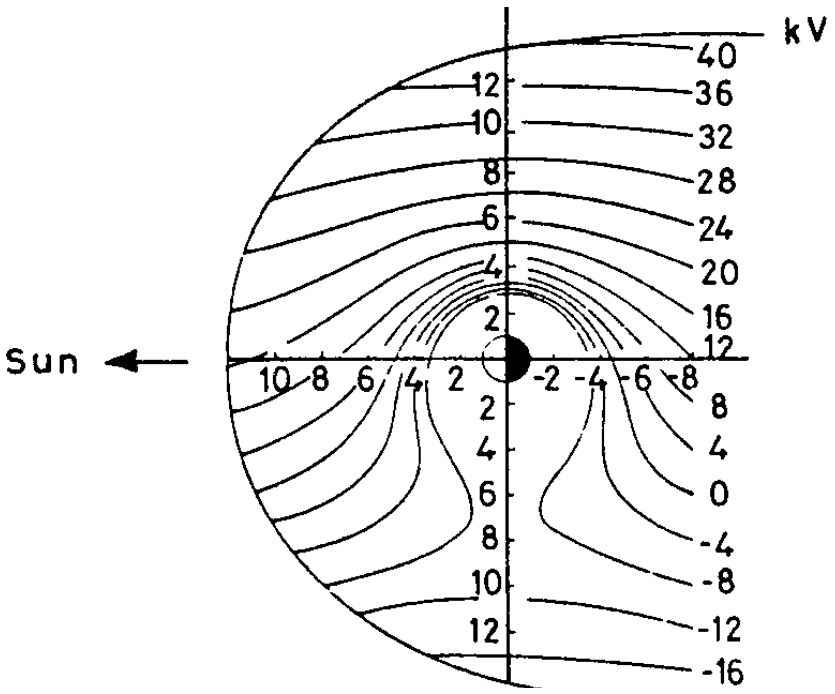
B. Overview

The morphology and dynamics of the plasmasphere / plasmasheet boundary (plasmapause) has been the subject of some study in the past, mainly utilizing the geostationary data [*Moldwin et al.*, 1994].

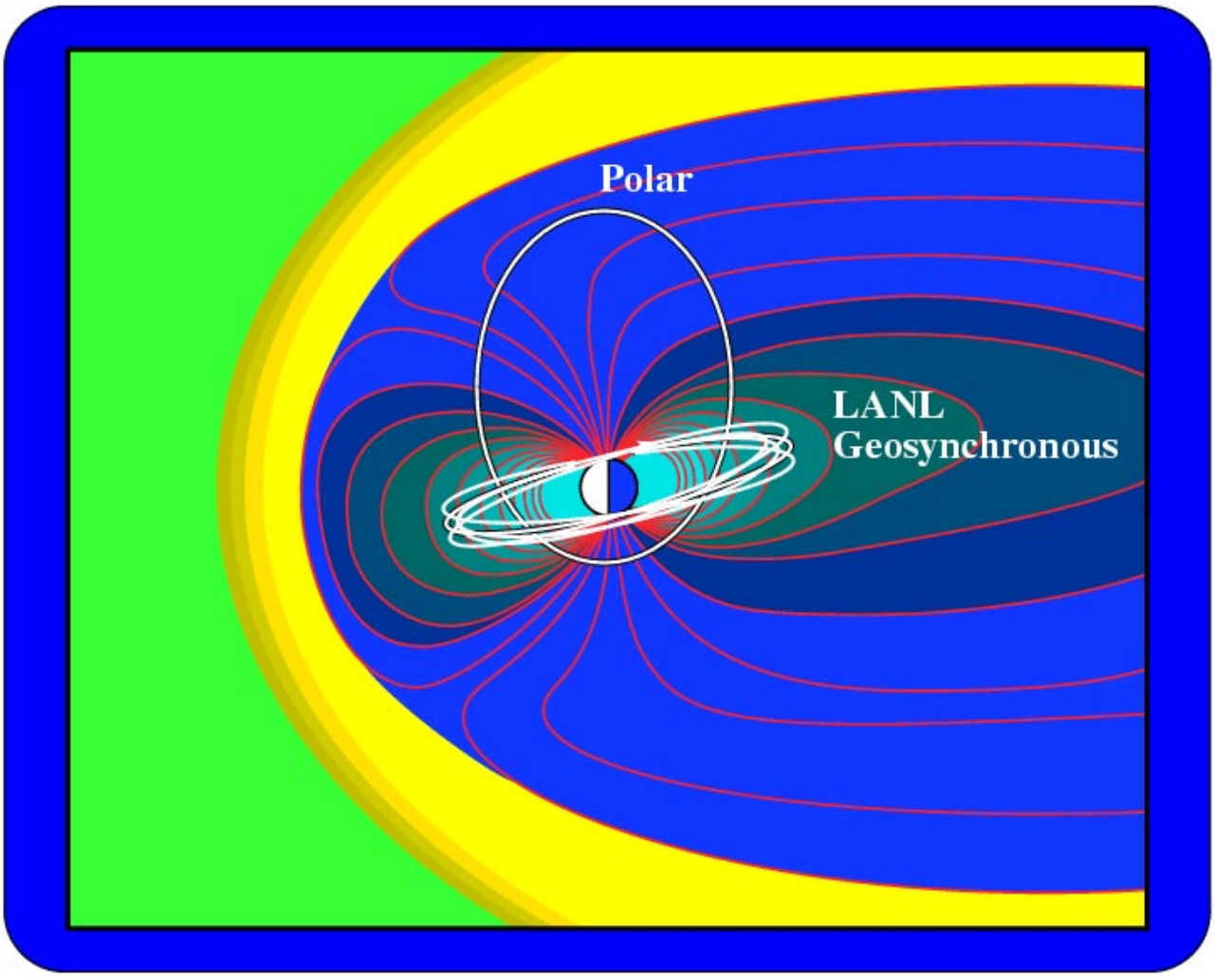
The traditional picture of the cold plasmaspheric boundary is the boundary between closed and open equipotentials formed by the superposition of co-rotating and dawn–dusk electric fields. While this is true in the statistical sense, the boundary at any given time might look very different.



The 3-dimensional structure of this boundary remains largely unexplored. Here POLAR offers the opportunity of probing the off-equatorial structure of this boundary.

C. Satellites

POLAR has an elliptical orbit about 1.8 to 9 R_E at 86^o inclination. POLAR cuts through the L-shell range of the "traditional" plasmapause, L = 7–4, four times each orbit, at medium magnetic latitudes of -50^o–$+50^o$. This range of latitudes make an ideal probe for the "thickness" of the plasmasphere. LANL operates up to 5 geosynchronous satellites located at a range of local times.



D. Instrumentation

Three POLAR instruments and one LANL geosynchronous instrument are used for this study:

A. HYDRA for electrons and ions from 0.02-20 keV (no composition) [*Scudder et al.*, 1995]

B. CAMMICE for ions 1–200 keV (energetic ion composition)

C. PWI [*Gurnett et al.*, 1995], the plasma wave instrument

D. MPA, the LANL plasma analyzer for ions 1–10000 eV, [*McComas et al.*, 1993]

HYDRA at times can sample the hot tail of the cold plasmaspheric ion distribution, while PWI data can be used to identify the plasmapause by the presence of the upper hybrid resonance line. CAMMICE is used to identify disturbed background conditions and the open/closed field line boundary.

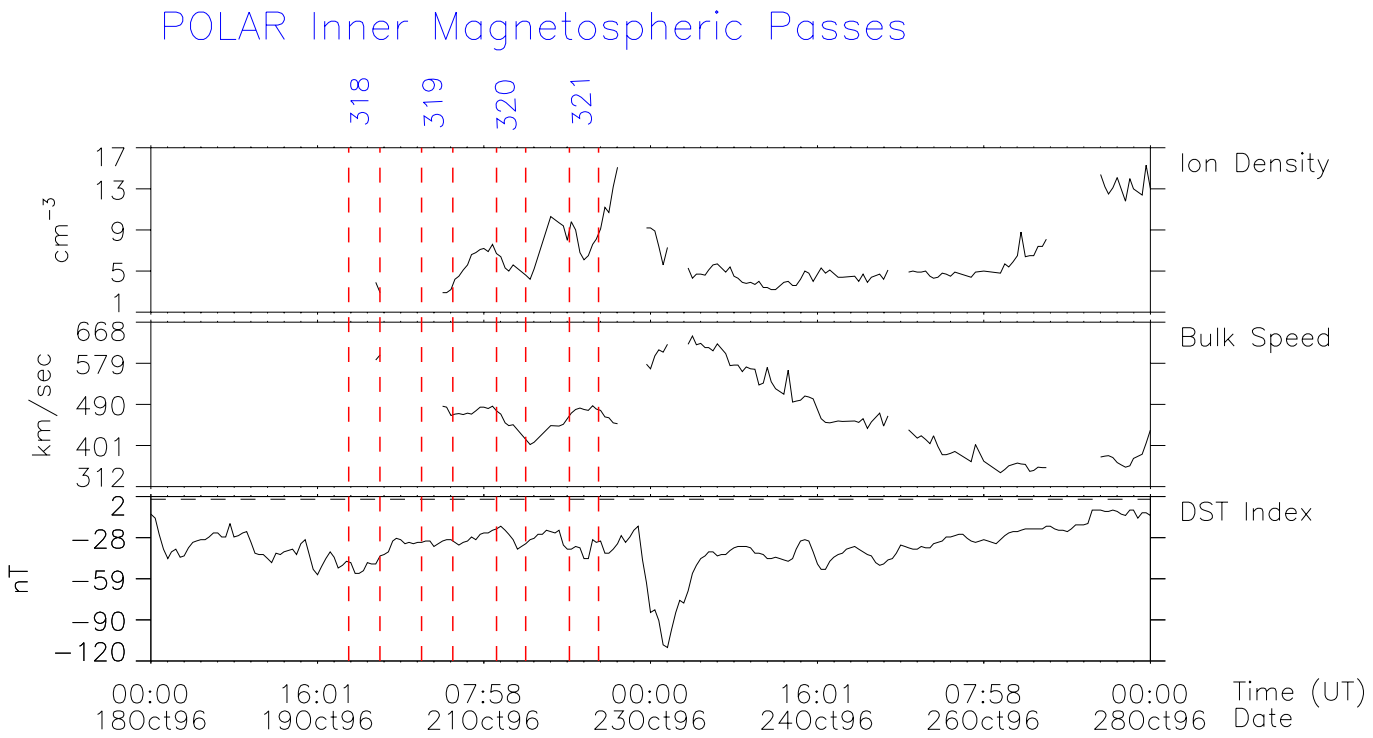
MPA identifies the plasmasphere by the presence of cold plasmaspheric ions that can be clearly seen in the data as high fluxes near 10eV.

E. Data interval chosen

A comprehensive search of the data was done to identify periods when POLAR HYDRA observes the hot tail of the cold plasmaspheric ions. This search was limited by the availability of PWI data to 1996, and to times when HYDRA was in the correct sweep mode. Plots are available at http://nis-www.lanl.gov/~friedel/plots/fallagu98/

Out of 400 orbits searched several around the October, 1996 magnetic storm showed a clear signature of plasmaspheric ions in the HYDRA data:

Orbits 318 - 321, October 20 – 22 1996



F. Description of plots

The following plots combine ion data from HYDRA, CAMMICE, MPA and PWI:

We select here only the times when POLAR traverses the inner magnetosphere, roughly three hours either side of perigee. The POLAR L-value is shown in the top panel while the extra x-axis labels give the POLAR magnetic local time and magnetic latitude.

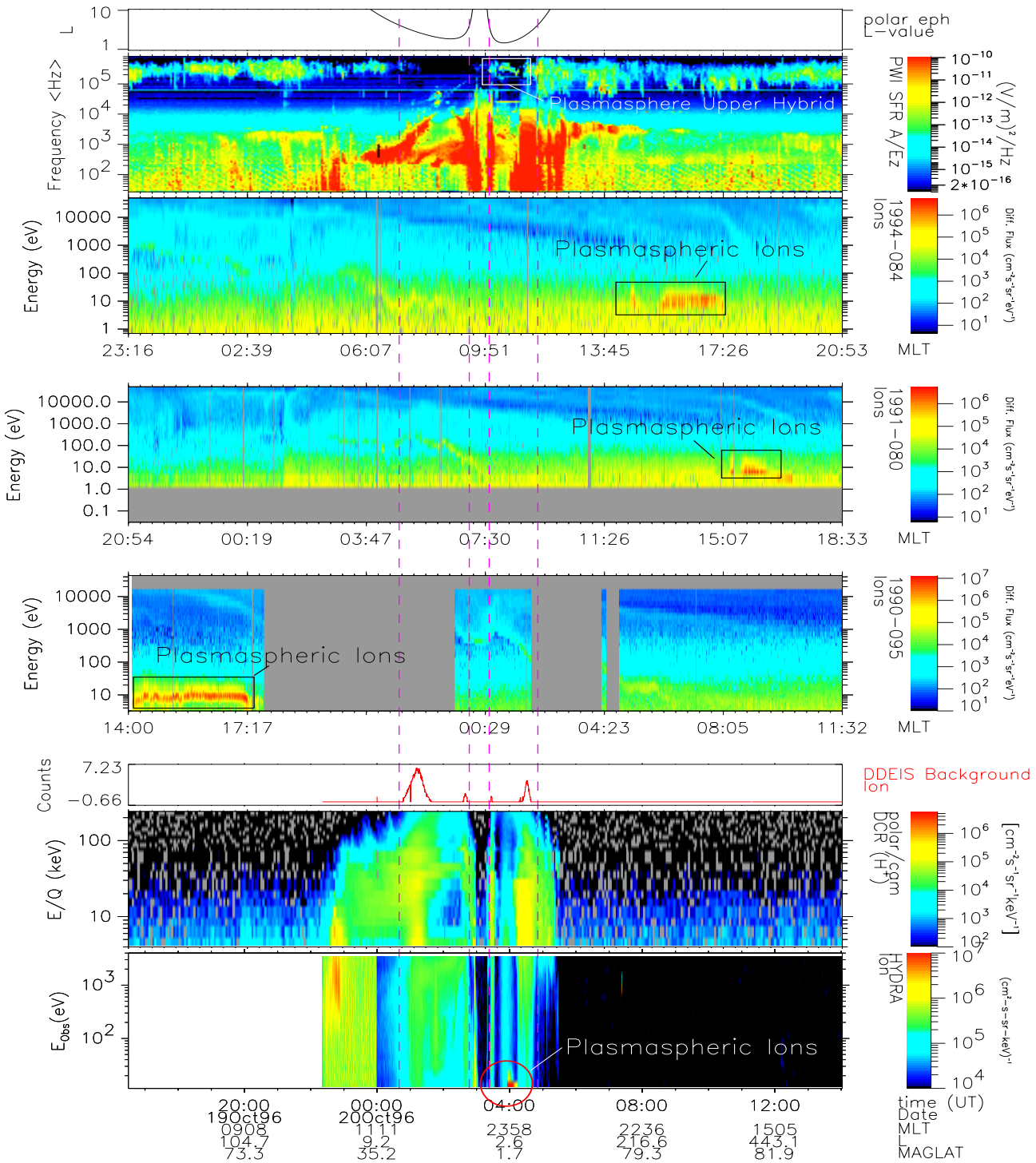
MPA spectra for all LANL geostationary satellites available for the given time are shown, together with their magnetic local time. The dashed red lines indicate the times when POLAR crosses the geostationary L-shell ($L = 6.6$) for comparison.

HYDRA and CAMMICE spectra are shown such that there is continuous energy coverage from one instrument to the other.

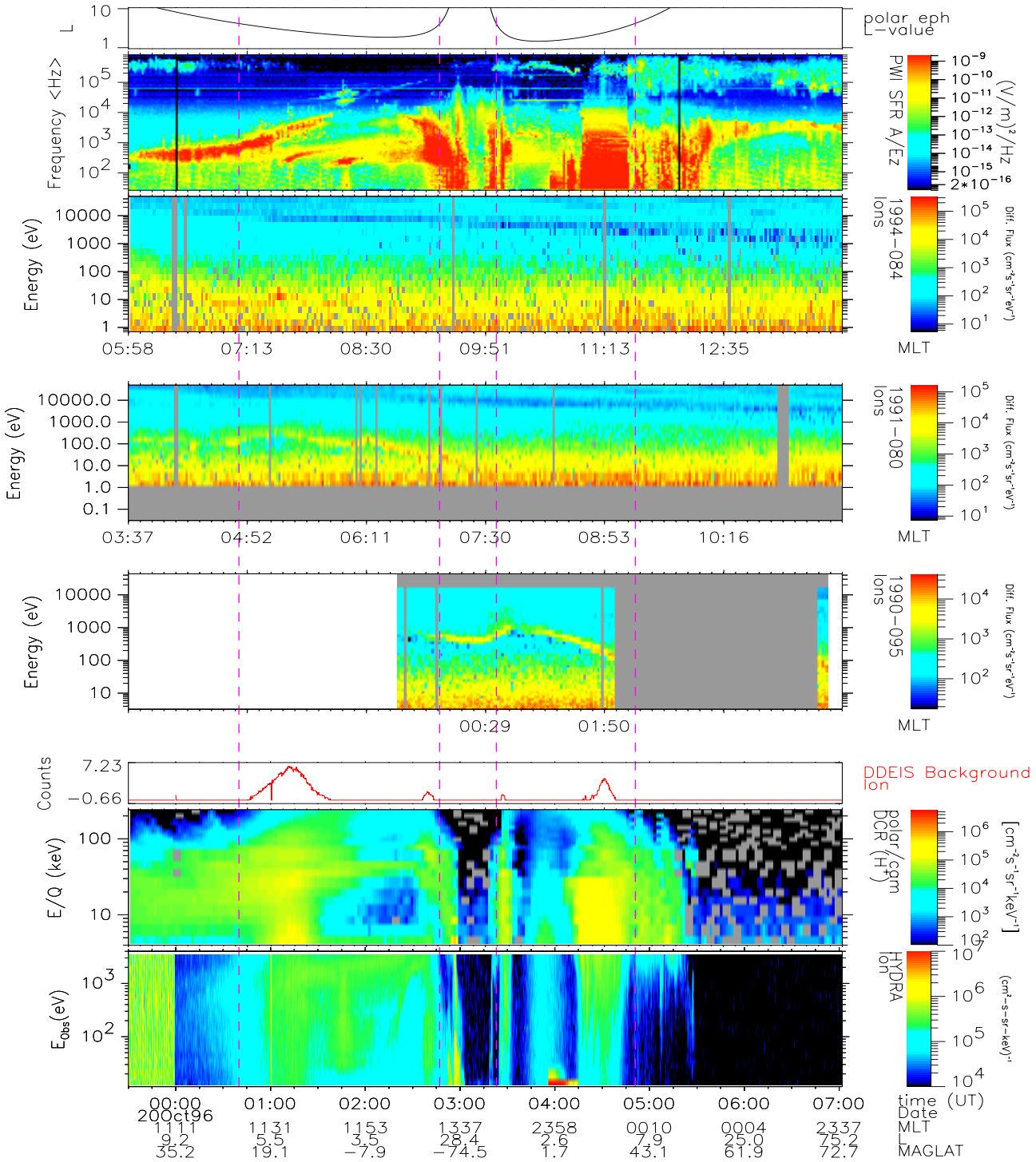
The HYDRA background channel is used as a check. For high background levels HYDRA ions are swamped in the inner magnetosphere and are not usable.

The high latitude inbound and outbound traverses through the inner magnetosphere are considered here. For orbits 318–321 they are at roughly constant MLT of 12:00 and 00:00 hours respectively.

G.1a POLAR Orbit 318: Full View



G.1b POLAR Orbit 318: Inner Magnetosphere



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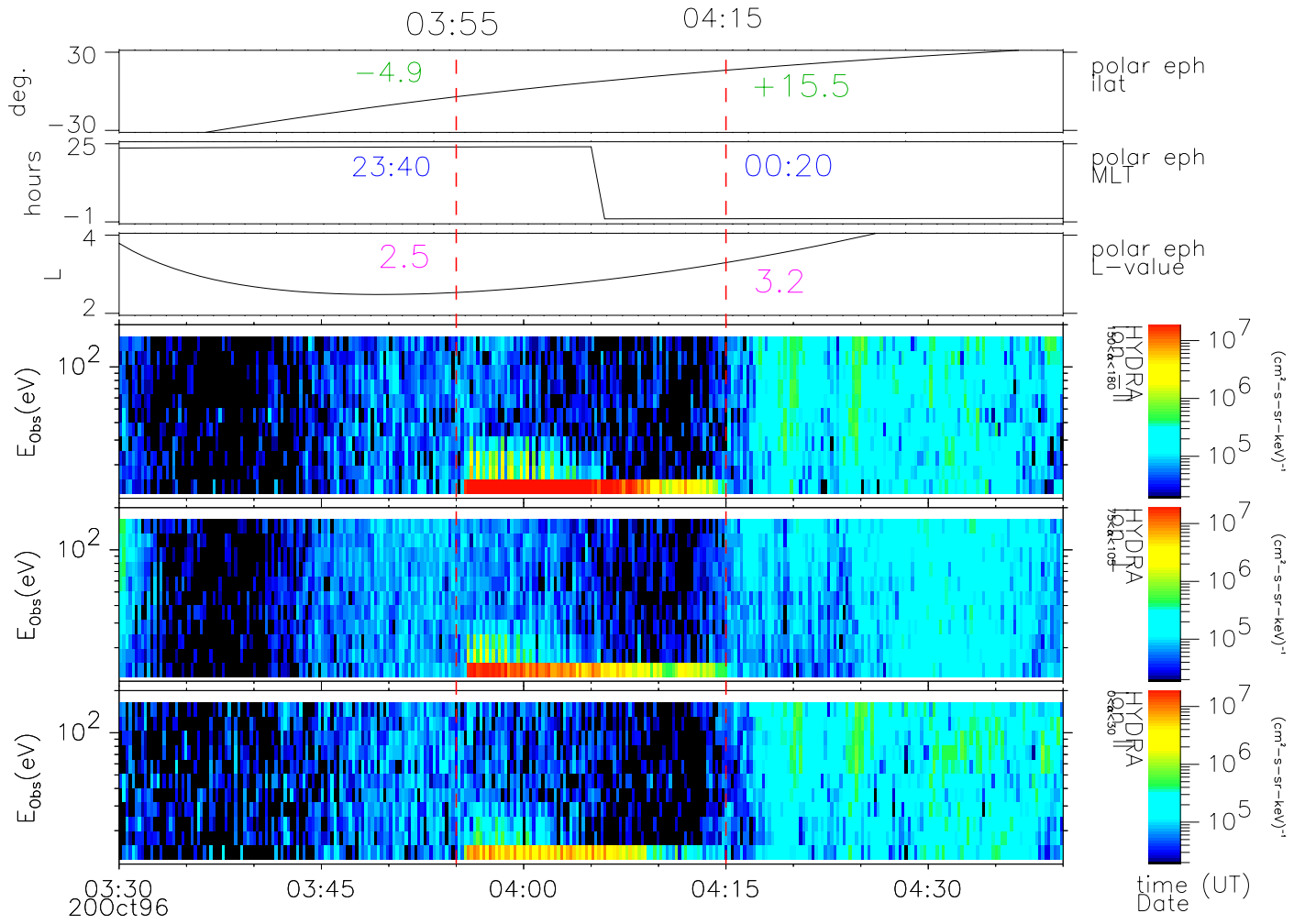
G.1c POLAR Orbit 318: HYDRA Detail



The hot plasmaspheric ions are seen at all pitch angles and have energies up to 30 eV at lower L, and are very localized in MLT.

The population exists at all pitch angles - higher intensities in the $B_{-\|}$ direction are due to the ram pressure of POLAR moving upwards through the magnetic equator.

G.1d POLAR Orbit 318: Description

We use the local time of entry / exit of satellite from cold plasmaspheric ion regions to get a position of the boundary:

Sat-ID	Hours MLT	UT	Date
1990-095:	12:40 to 17:00	$\sim$ 18:00	10/19/1996
1994-084:	13:50 to 17:15	$\sim$ 09:15	10/20/1996
1991-080:	14:45 to 16:00	$\sim$ 11:15	10/20/1996

LANL here see the afternoon plasmaspheric bulge only.

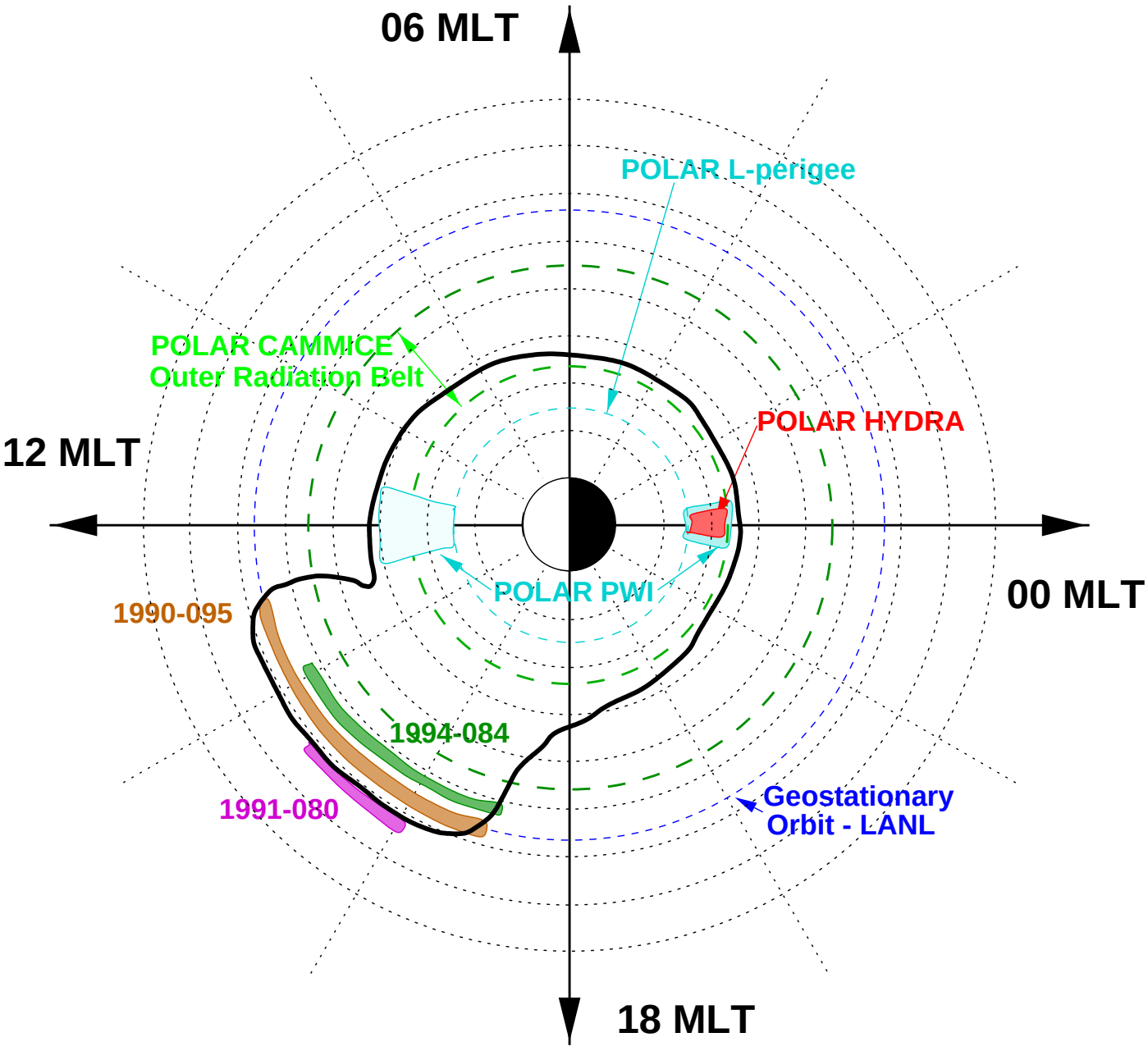
HYDRA encounters the high energy tail of the cold plasmaspheric ions briefly on the outbound pass near 04:00 UT, 10/20/1996 (dipole model):

Magnetic Local Time:	24:40 – 00:20	hours
L-value:	2.5 (perigee) – 3.2	
Magnetic latitude:	-4.9 – 15.5	degrees

PWI shows the plasmashere position by the presence of the upper hybrid resonance frequency (dipole model):

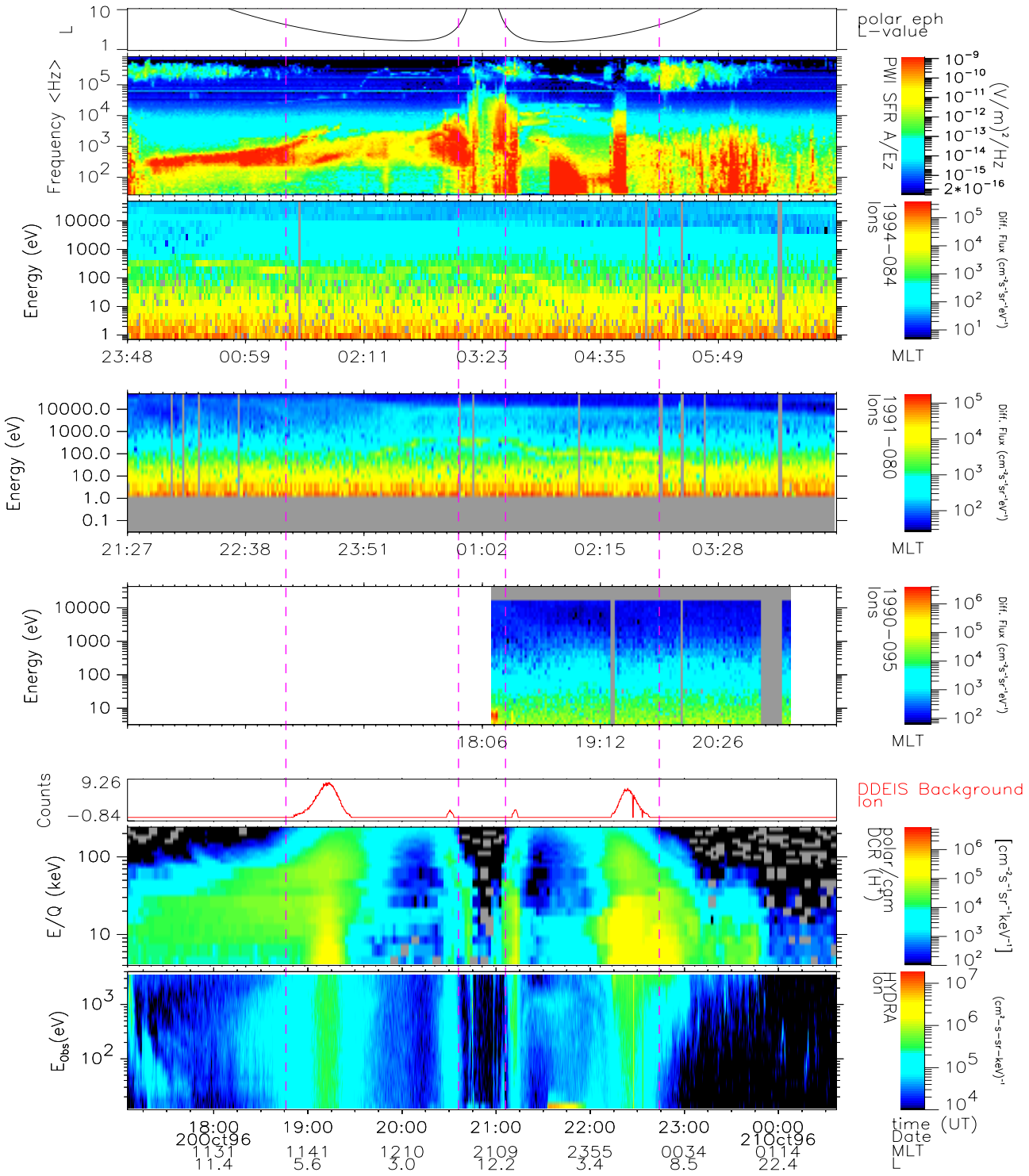
	inbound ($\sim$ 02 UT	outbound ($\sim$ 02 UT)
MLT (hr):	11:30 – 12:40	23.30 – 00:20
L:	2.5 (perigee) - 4.0	2.5 (perigee) – 3.4
MLAT (deg):	-45 – 20	-36.0 – 15.5
confidence:	– low –	– moderate –

G.1e POLAR Orbit 318: Plasmasphere morphology



Hot plasmaspheric ions are observed at the outer edge of the plasmasphere which here is also the inner edge of the outer radiation belt, and in a region limited to local midnight.

G.2 POLAR Orbit 319: Inner Magnetosphere



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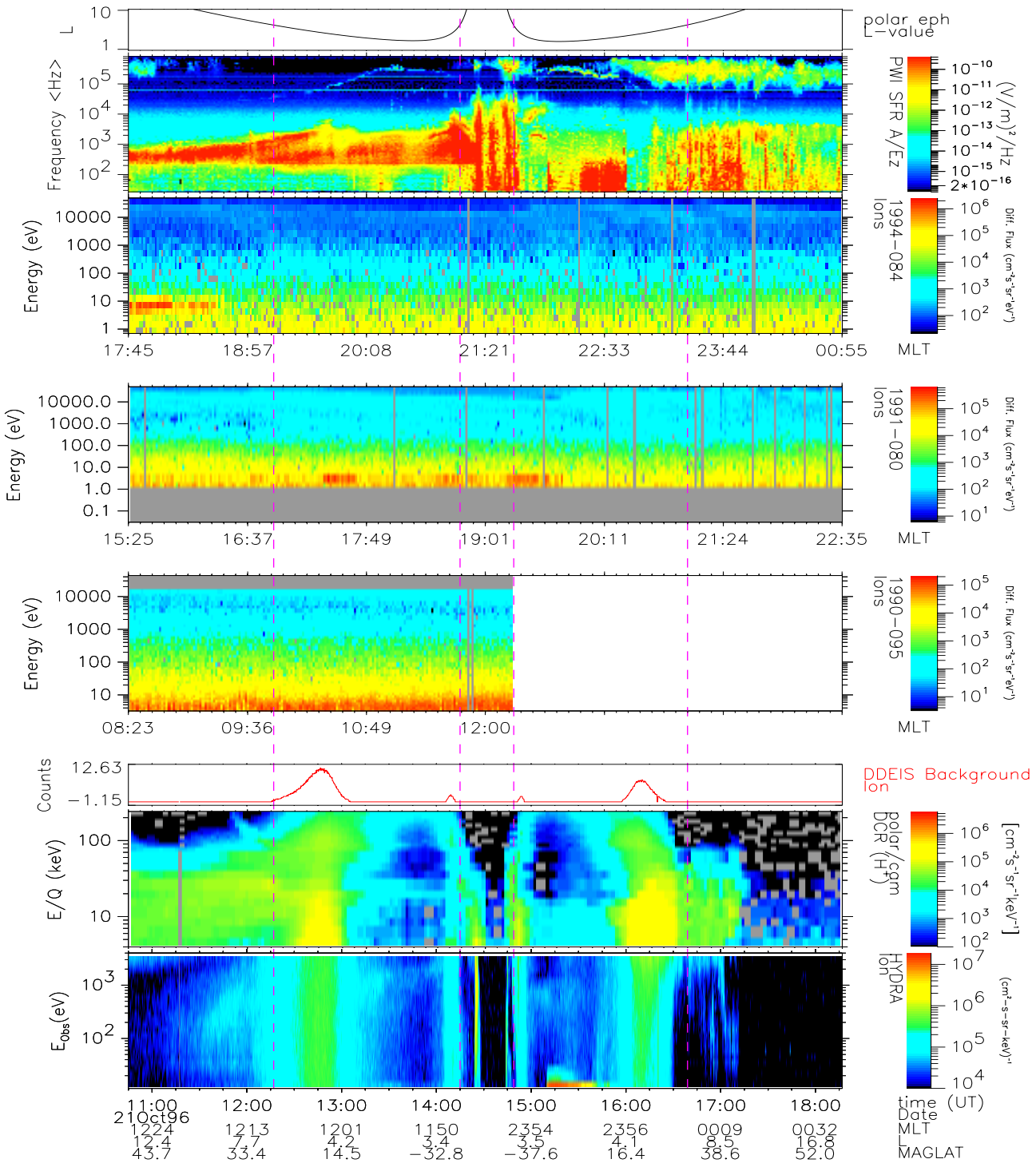
G.3 POLAR Orbit 320: Inner Magnetosphere



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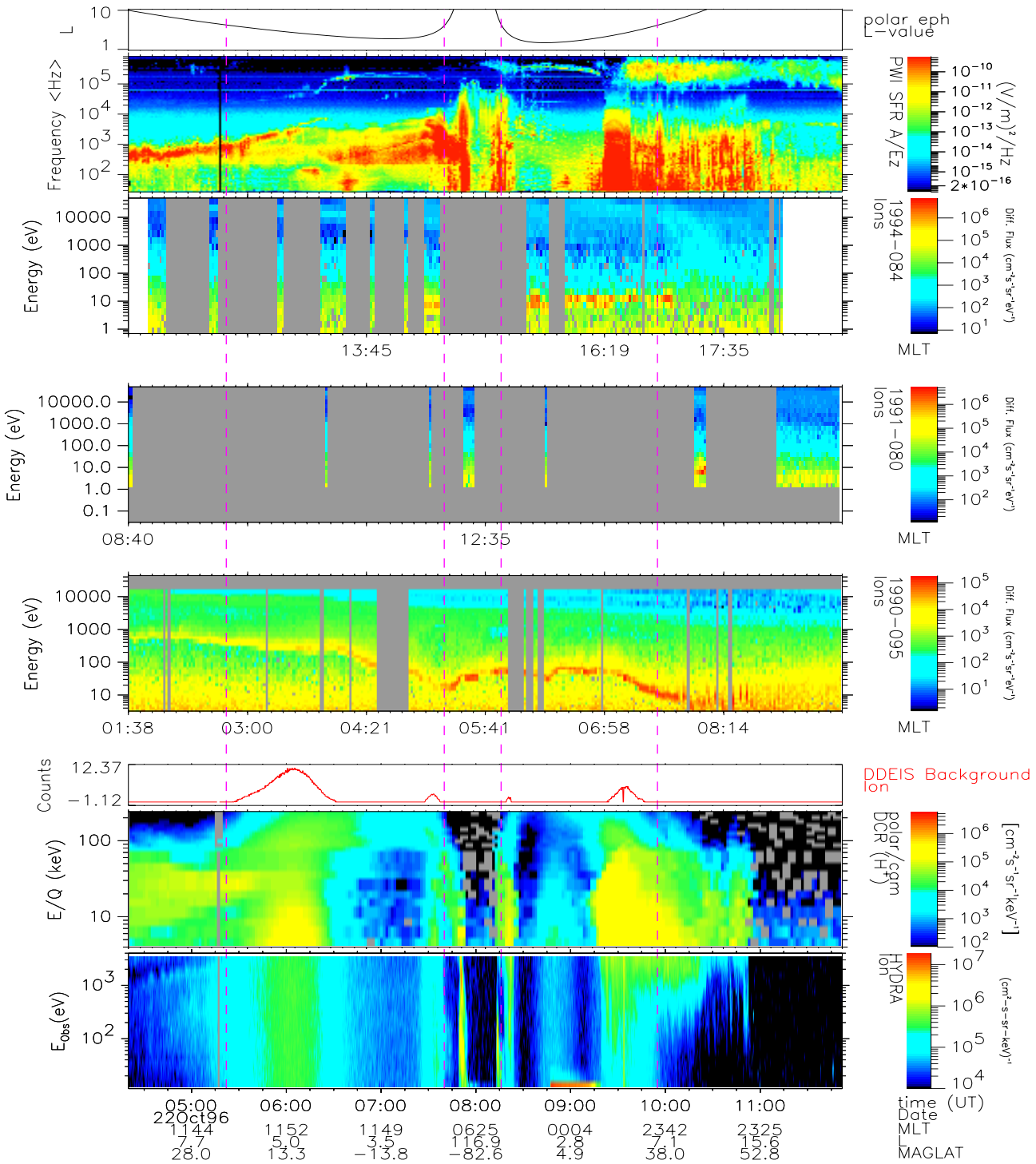
G.4 POLAR Orbit 321: Inner Magnetosphere



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H. POLAR Orbit 318-321: Summary

- The hot tail of the plasmaspheric ion population is seen by HYDRA for four consecutive orbits at basically the same position and with the same characteristics:
  - At the outer edge of the plasmashere
  - At the inner edge of the outer radiation belt
  - Basically isotropic
  - Getting hotter at lower L
  - Very localized in MLT
- HYDRA does not show any background contamination at these times!
- MPA shows a consistent afternoon bulge over this period: The plasmashere seems very "static".
- With HYDRA seeing the plasmasphere at much lower L at the night-side the plasmapause seems to be located near L=4 at most other MLT
- PWI shows a clear midnight signature of the plasmasphere, a weak midday signature.
- The plasmasphere is reconfigured with the magnetic storm onset on the morning of October 23, 1996: The hot tail of the plasmaspheric ion population disappears.

I. Conclusion

- The hot tail of the cold plasmaspheric population (tens of eV) is a largely unexplored plasma signature in the inner magnetosphere. It has been observed at times in MPA data at the entry/exit into the plasmasphere, and at all local times. (See further example for POLAR orbit 147).
- Measurements from POLAR here show this signature at Much lower L as well and very localized in MLT.
- Conditions for the occurrence of this signature have not been fully established. From the events studies here it seems that
  - generally quiet conditions
  - a fairly static plasmasphere

  are needed. This signature is wiped out by storm onset.
- So far only this one period has been observed with POLAR. This might be due to instrumental effects - HYDRA cannot reliably sample low ion energies when contaminated by background: The plasmashere needs to be very contracted to be "below" the radiation belts.

J. References

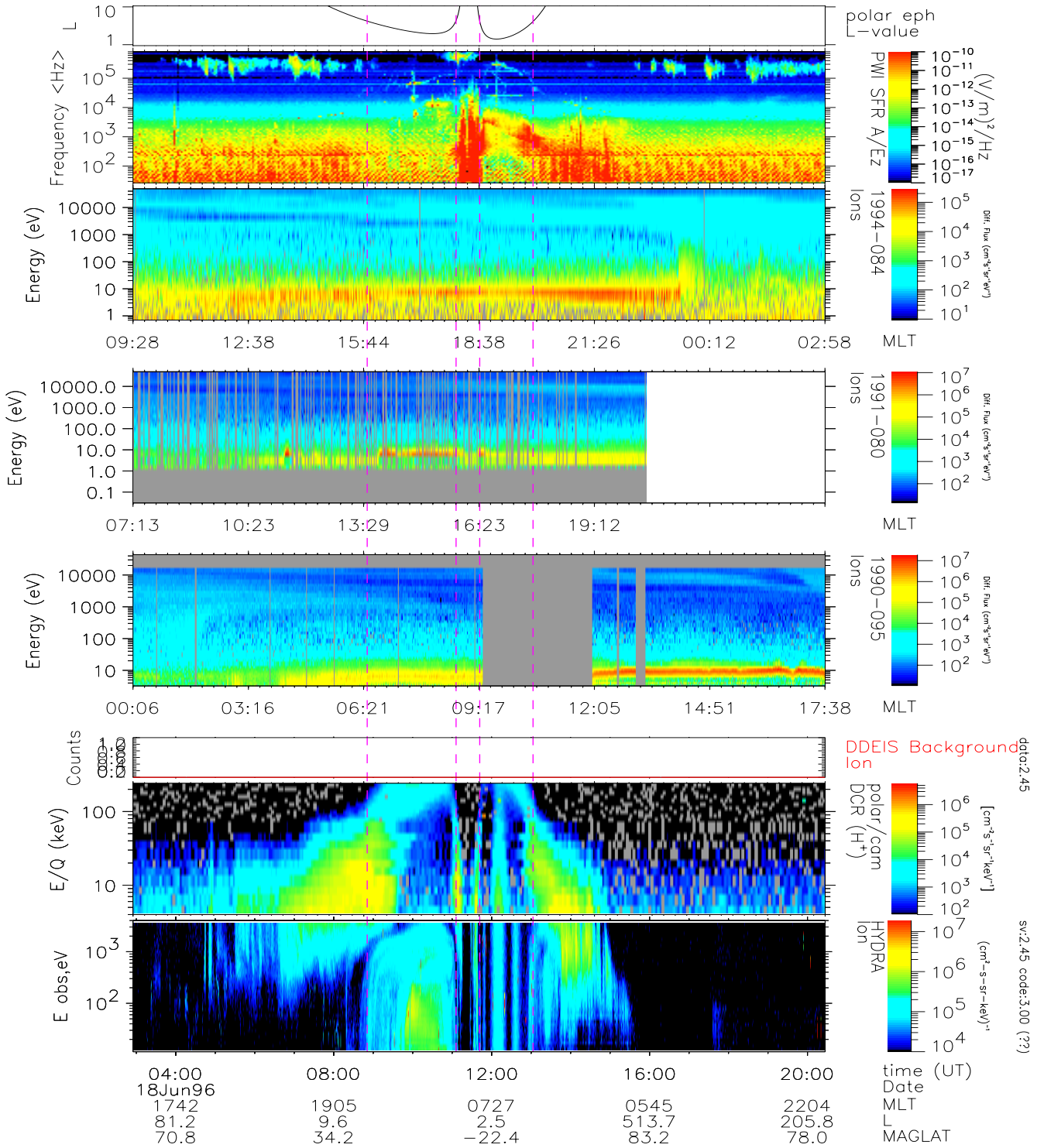
Gurnett, D. A., et al., The POLAR plasma wave instrument, *Space Sci. Rev*, *71*, 597–622, 1995.

McComas, D. J., et al., Magnetospheric plasma analyzer (mpa): Initial three-spacecraft observations from geosynchronous orbit, *J. Geophys. Res.*, *98*, 13,453, 1993.

Moldwin, M. B., M. F. Thomsen, S. J. Bame, D. J. McComas, and K. R. Moore, An examination of the structure and dynamics of the outer plasmasphere using multiple geosynchronous satellites, *J. Geophys. Res.*, *99*, 11,475–11,481, 1994.

Scudder, J., et al., Hydra - a 3-dimensional electron and ion hot plasma instrument for the POLAR spacecraft of the GGS mission, *Space Sci. Rev*, *71*, 459–495, 1995.

Further example: Orbit 149 Full



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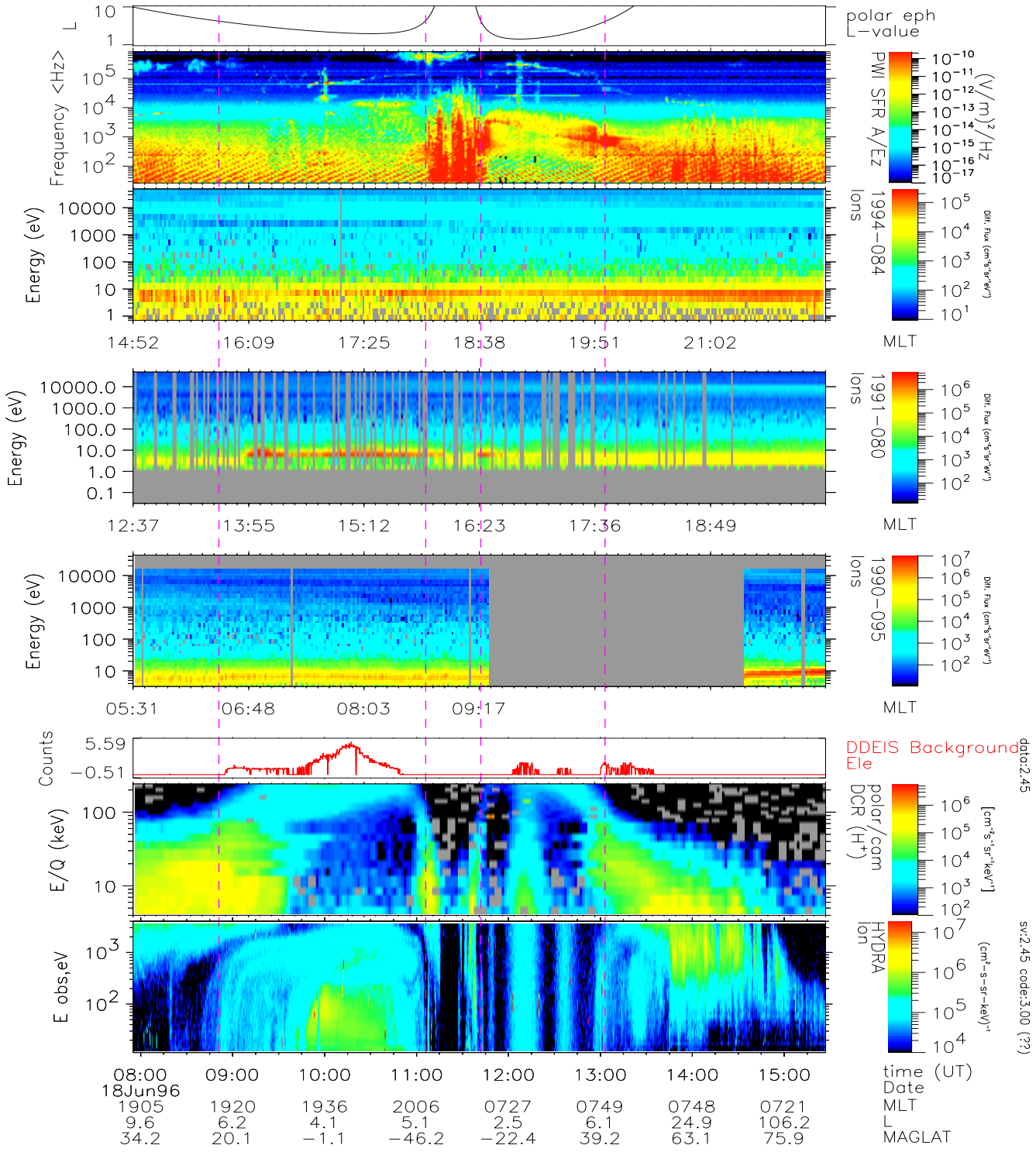
Further example: Orbit 149 Inner Magnetosphere



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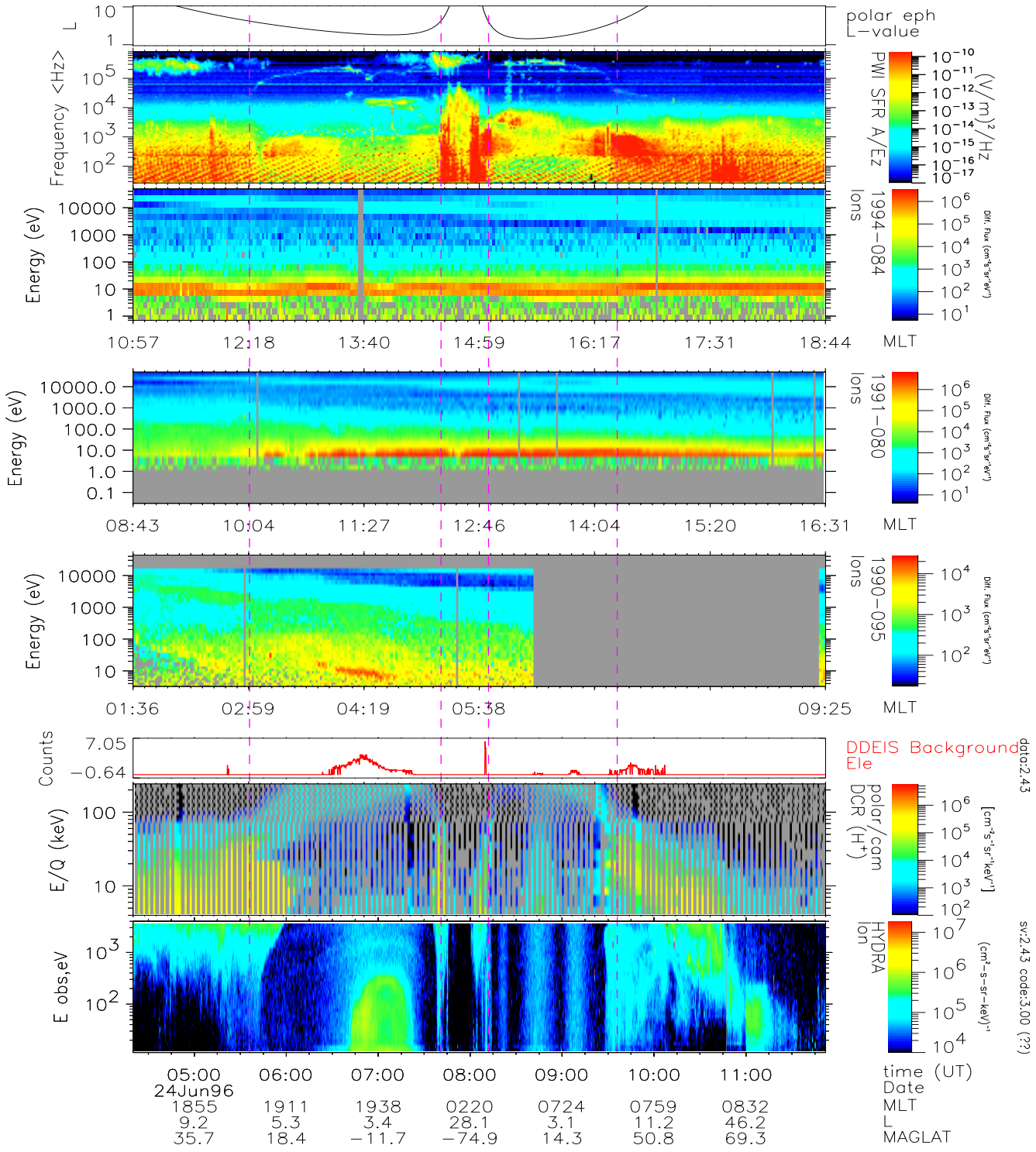
Further example: Orbit 157 Inner Magnetosphere



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